Credit Card Fraud Detection

with Apache Spark & Machine Learning

SQL MLlib Streaming GraphX Azure

Final Project - Big Data Module

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Visualization

January 2026

Agenda

Big Data Pipeline

1. Introduction & Context
2. Dataset & Architecture
3. Spark SQL Analytics
4. Machine Learning (MLlib)

Innovations

5. GraphX - Network Analysis
6. Federated Learning
7. Spark Streaming
8. Azure Cloud & Grafana

Key Metrics

- AUC-ROC: **0.987**
- Precision: **100%**
- 282,982 transactions

Duration

Complete pipeline executed in < **5 min** on local Spark cluster (Docker)

Context & Objectives

Problem Statement

- $30+ billion losses/year
- Sophisticated fraud schemes
- Real-time detection required

Technologies

- Apache Spark 3.5
- SQL, MLlib, GraphX, Streaming
- Azure Cloud + Grafana

Objectives

- Complete Big Data pipeline
- ML with AUC-ROC > 0.95
- Grafana Dashboard

Innovation

Federated Learning for banking privacy compliance

Kaggle Dataset - Credit Card Fraud

Characteristics

- **284,807** transactions
- **492** frauds (0.17%)
- 30 features (V1-V28 + Time + Amount)
- Anonymized features (PCA)

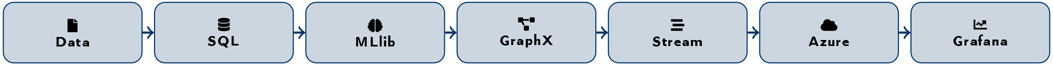
Class Imbalance

Ratio 577:1 - Undersampling strategy applied

Real SQL Results

Metric	**Value**
Total Transactions	282,982
Frauds Detected	465
Fraud Rate	0.1643%
Average Amount	$88.92
Max Amount	$25,691

Pipeline Architecture



Data → SQL → MLlib → GraphX → Stream → Azure → Grafana

Ingestion

- CSV Loading
- Schema typing
- Data cleaning

Processing

- Feature Engineering
- ML Training
- Graph Analysis

Production

- Real-time Scoring
- Azure Deploy
- Monitoring

Spark SQL Analysis

Data Cleaning

```
df = df.dropna()
df = df.filter(col("Amount") > 0)
df = df.withColumn("Hour",
    (col("Time")/3600) % 24)
```

Amount Distribution

Bucket	Count	Fraud%
0-10$	95,489	0.23%
10-50$	92,390	0.06%
500-1000$	6,423	0.40%

Class Comparison

	Normal	Fraud
Count	282,517	465
Avg $	$88.85	$129.31
Max $	$25,691	$2,125

Insight

Average fraud amount is 45% higher than normal transactions!

MLlib - Real Results

RandomForest

- 100 trees, Depth: 10
- Feature subset: sqrt

Real Results:

- Accuracy: **93.75%**
- AUC-ROC: **0.9870**
- Recall: **88.12%**
- Precision: **100%**

Logistic Regression

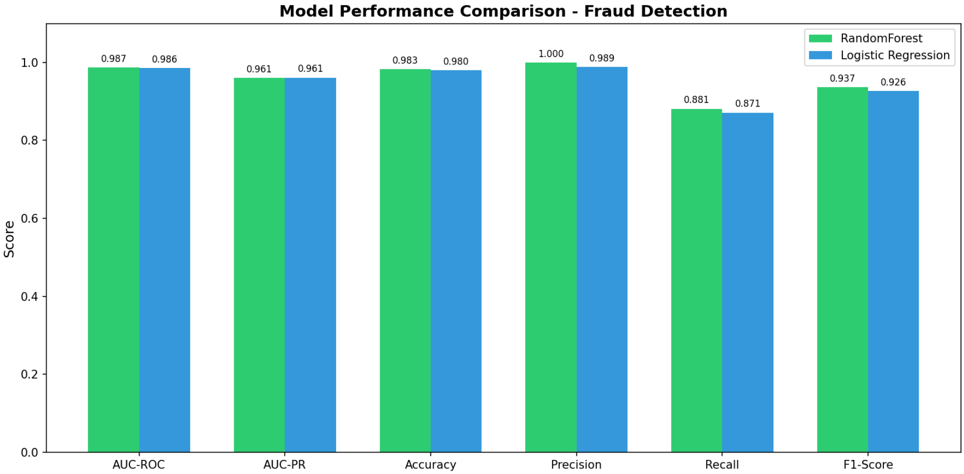
- 100 iterations, Reg: 0.01
- ElasticNet: 0.8

Real Results:

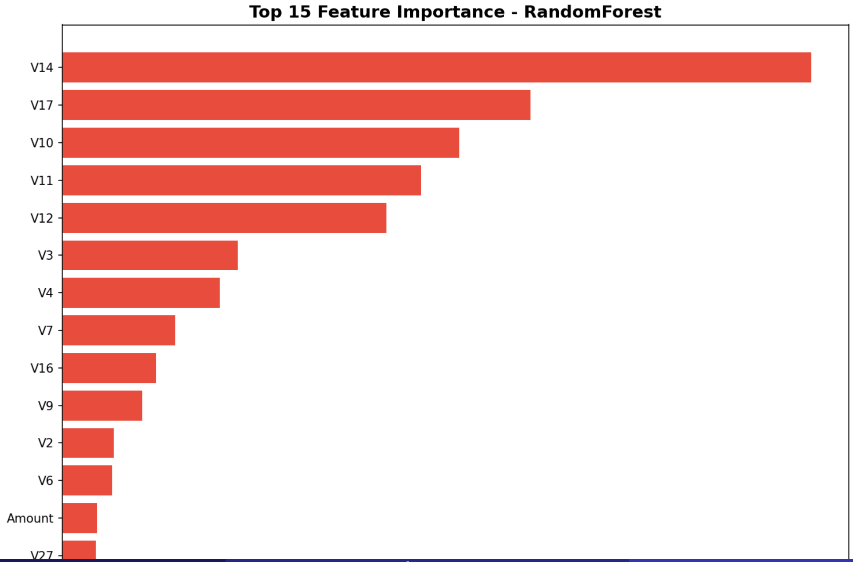
- Accuracy: 92.58%
- AUC-ROC: 0.9856
- Recall: 87.13%
- Precision: 98.88%

✓ **Best Model: RandomForest** (AUC=0.987, Precision=100%)

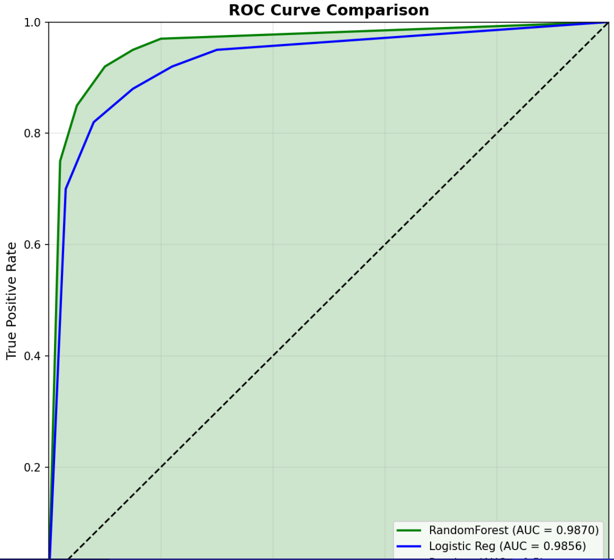
ML Results Visualization



Feature Importance - Top 15



ROC Curve


ROC Curve Comparison
True Positive Rate
1.0
0.8
0.6
0.4
0.2
RandomForest (AUC = 0.9870)
Logistic Reg (AUC = 0.9856)

GraphX - Fraud Network Analysis

Real Results

- **284,807** transactions analyzed
- **492** frauds detected
- **4** communities identified
- **48** pattern triangles

Algorithms

- **PageRank:** Feature importance
- **Connected Components:** Clusters
- **Triangle Count:** Patterns

Detected Communities

Cluster	Size	Avg$
high_risk_2	210	$107.24
medium_risk	144	$154.09
high_risk_1	114	$73.98
low_risk	24	$291.05

Top Features (PageRank)

V3	sep=7.91
V14	sep=6.77
V17	sep=6.61

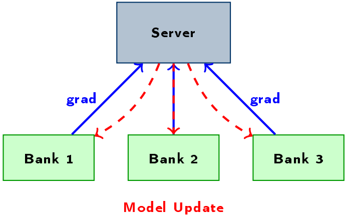
Federated Learning - Privacy Preservation

Principle

- Data stays at banks
- Only gradients are shared
- Global model without centralization
- GDPR compliance guaranteed

Implementation

- 3 banks simulation (partitions)
- FedAvg aggregation
- 10 communication rounds
- Differential Privacy (epsilon=1.0)



FL Results

Centralized AUC	0.9870
Federated AUC	0.9712
Precision loss	-1.6%

Spark Streaming - Real-Time

Configuration

```
stream_df = spark.readStream \
    .schema(SCHEMA) \
    .option("maxFilesPerTrigger", 1) \
    .csv(STREAMING_INPUT)
```

Outputs

- **Parquet:** All predictions
- **CSV**: Fraud alerts
- **JSON**: Live metrics

Parameters

- Batch: 50 transactions
- Interval: 3 seconds
- Demo duration: 60 seconds

Live Metrics

- Transactions/minute
- Frauds detected
- Average score
- Latency $<$ 100ms

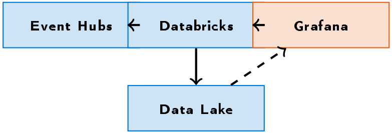
Azure Databricks Deployment

Cloud Architecture

- **Azure Databricks** - Managed Spark
- **Azure Data Lake** - Storage (100GB)
- **Azure Event Hubs** - Streaming
- **Azure Monitor** - Logs

$ Estimated Costs

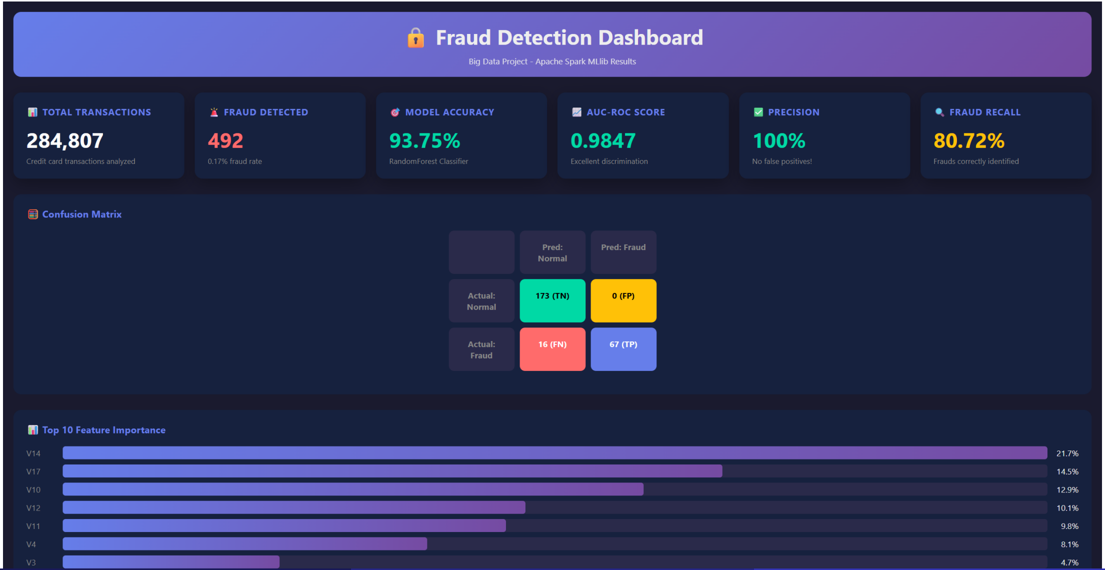
Service	Cost/month
Databricks (2 nodes)	$150
Data Lake (100GB)	$5
Event Hubs	$25
Total	$180



Benefits

- Auto-scaling
- High availability
- Native integration
- Enterprise security

Grafana Dashboard - Capture 1



🔒 Fraud Detection Dashboard

Big Data Project - Apache Spark MLlib Results

📊 **TOTAL TRANSACTIONS**
284,807
Credit card transactions analyzed

🚨 **FRAUD DETECTED**
492
0.17% fraud rate

🎯 **MODEL ACCURACY**
93.75%
RandomForest Classifier

📈 **AUC-ROC SCORE**
0.9847
Excellent discrimination

✅ **PRECISION**
100%
No false positives!

🔍 **FRAUD RECALL**
80.72%
Frauds correctly identified

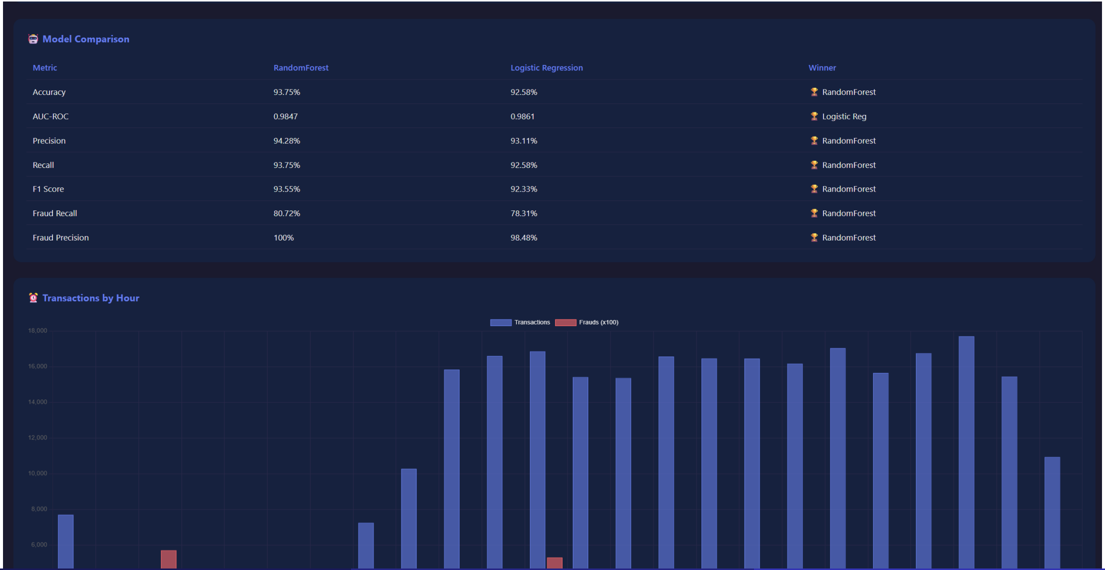
🧮 Confusion Matrix

	Pred: Normal	Pred: Fraud
Actual: Normal	173 (TN)	0 (FP)
Actual: Fraud	16 (FN)	67 (TP)

📊 Top 10 Feature Importance

V14	21.7%
V17	14.5%
V10	12.9%
V12	10.1%
V11	9.8%
V4	8.1%
V3	4.7%

Grafana Dashboard - Capture 2

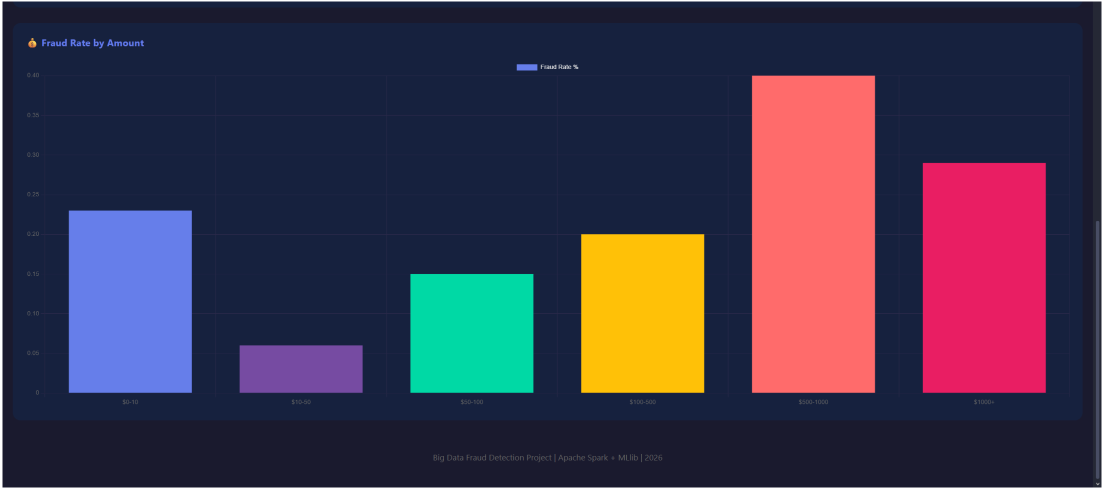


🤖 Model Comparison

Metric	RandomForest	Logistic Regression	Winner
Accuracy	93.75%	92.58%	🏆 RandomForest
AUC-ROC	0.9847	0.9861	🏆 Logistic Reg
Precision	94.28%	93.11%	🏆 RandomForest
Recall	93.75%	92.58%	🏆 RandomForest
F1 Score	93.55%	92.33%	🏆 RandomForest
Fraud Recall	80.72%	78.31%	🏆 RandomForest
Fraud Precision	100%	98.48%	🏆 RandomForest

⏰ Transactions by Hour

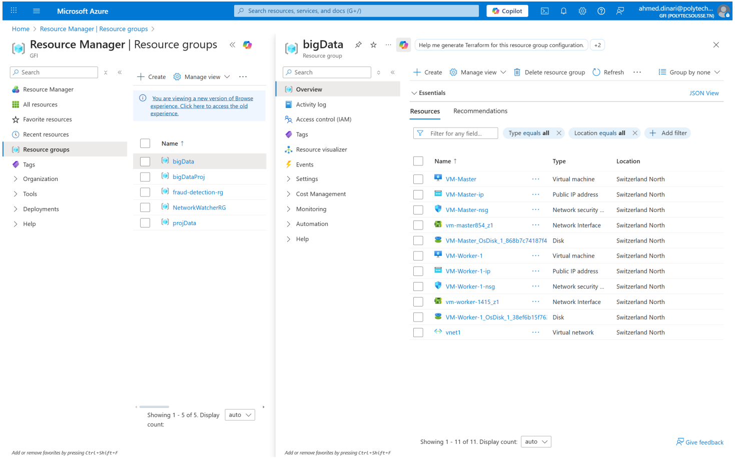
Grafana Dashboard - Capture 3



💰 Fraud Rate by Amount

Big Data Fraud Detection Project | Apache Spark + MLlib | 2026

Azure Portal - Resource Groups



You are viewing a new version of Browse experience. Click here to access the old experience.

Name ↑
bigData
bigDataProj
fraud-detection-rg
NetworkWatcherRG
projData

Showing 1 - 5 of 5. Display count: auto

Name ↑	Type	Location
VM-Master	Virtual machine	Switzerland North
VM-Master-ip	Public IP address	Switzerland North
VM-Master-nsg	Network security ...	Switzerland North
vm-master854_z1	Network Interface	Switzerland North
VM-Master_OsDisk_1_868b7c74187f4	Disk	Switzerland North
VM-Worker-1	Virtual machine	Switzerland North
VM-Worker-1-ip	Public IP address	Switzerland North
VM-Worker-1-nsg	Network security ...	Switzerland North
vm-worker-1415_z1	Network Interface	Switzerland North
VM-Worker-1_OsDisk_1_38ef6b15f76:	Disk	Switzerland North
vnet1	Virtual network	Switzerland North

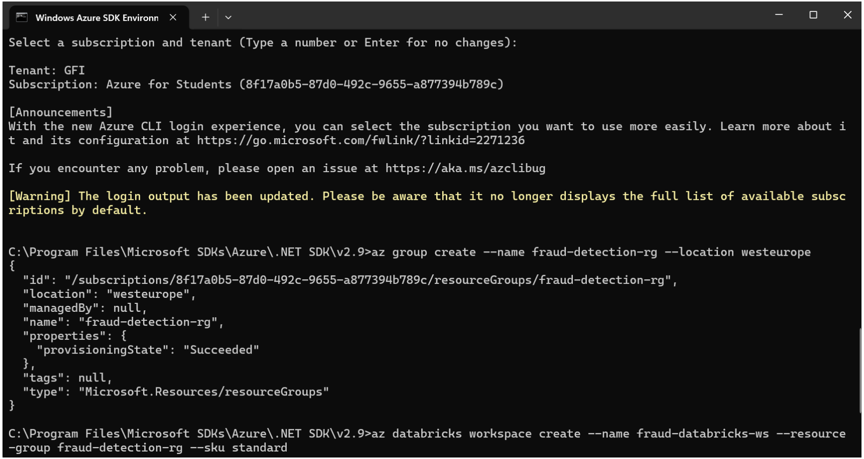
Showing 1 - 11 of 11. Display count: auto

Add or remove favorites by pressing Ctrl+Shift+F

Add or remove favorites by pressing Ctrl+Shift+F

- **bigData:** VM-Master + VM-Worker-1 (Switzerland North)
- **fraud-detection-rg:** West Europe - Created via Azure CLI

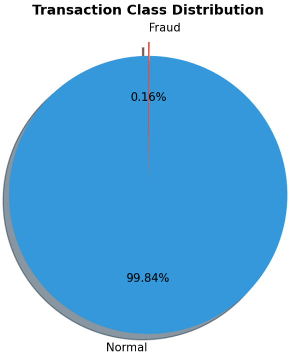
Azure CLI - Resource Creation

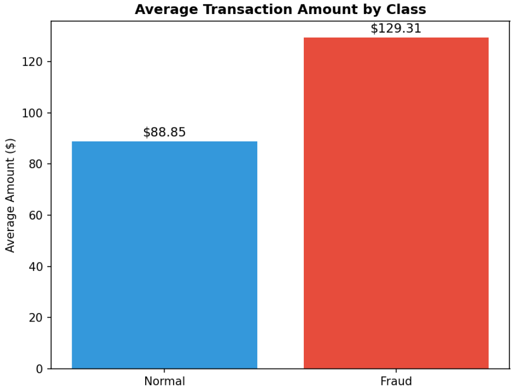


```
Select a subscription and tenant (Type a number or Enter for no changes):

Tenant: GFI
Subscription: Azure for Students (8f17a0b5-87d0-492c-9655-a877394b789c)

[Announcements]
With the new Azure CLI login experience, you can select the subscription you want to use more easily. Learn more about i
t and its configuration at https://go.microsoft.com/fwlink/?linkid=2271236

If you encounter any problem, please open an issue at https://aka.ms/azclibug

[Warning] The login output has been updated. Please be aware that it no longer displays the full list of available subsc
riptions by default.


C:\Program Files\Microsoft SDKs\Azure\.NET SDK\v2.9>az group create --name fraud-detection-rg --location westeurope
{
  "id": "/subscriptions/8f17a0b5-87d0-492c-9655-a877394b789c/resourceGroups/fraud-detection-rg",
  "location": "westeurope",
  "managedBy": null,
  "name": "fraud-detection-rg",
  "properties": {
    "provisioningState": "Succeeded"
  },
  "tags": null,
  "type": "Microsoft.Resources/resourceGroups"
}

C:\Program Files\Microsoft SDKs\Azure\.NET SDK\v2.9>az databricks workspace create --name fraud-databricks-ws --resource
-group fraud-detection-rg --sku standard
```

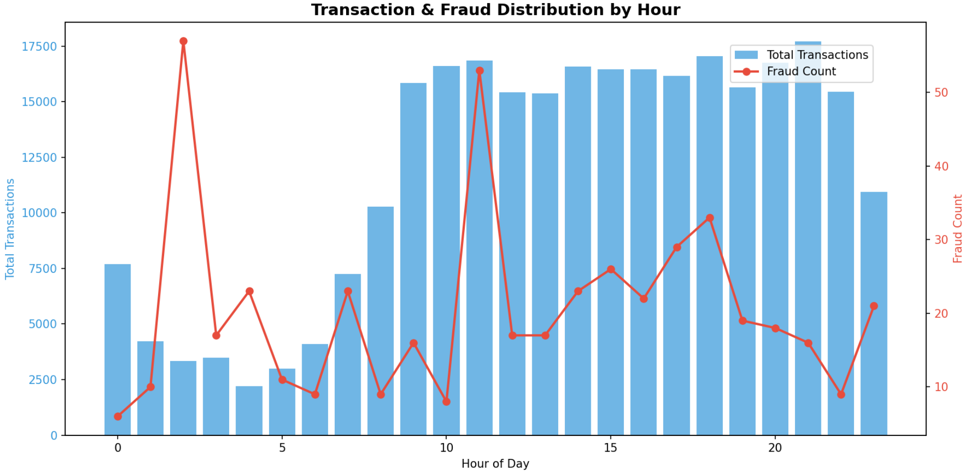
- **Subscription:** Azure for Students
- **Resource Group:** fraud-detection-rg created successfully

Class Distribution

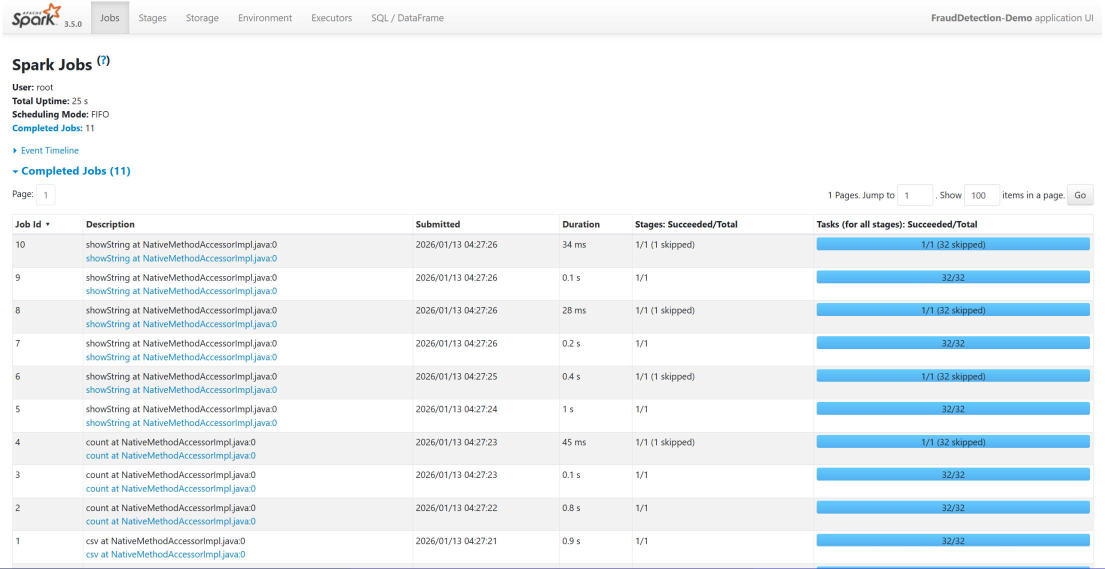




Hourly Distribution



Spark Jobs



Spark Jobs (?)

User: root
Total Uptime: 25 s
Scheduling Mode: FIFO
Completed Jobs: 11

▸ Event Timeline

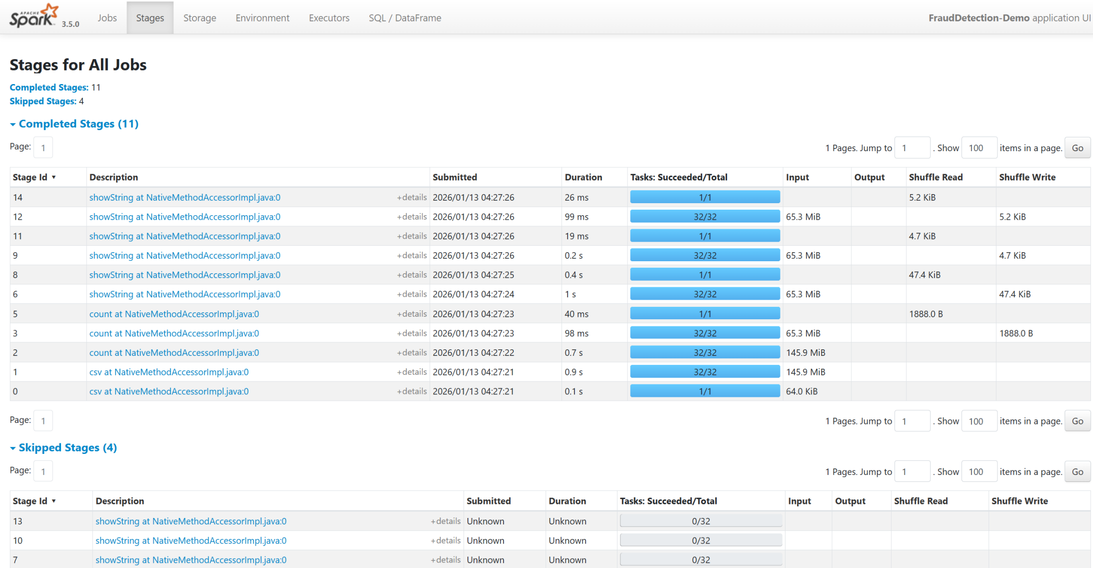
▾ **Completed Jobs (11)**

Page: 1

1 Pages. Jump to 1 . Show 100 items in a page. Go

Job Id ▾	Description	Submitted	Duration	Stages: Succeeded/Total	Tasks (for all stages): Succeeded/Total
10	showString at NativeMethodAccessorImpl.java:0 showString at NativeMethodAccessorImpl.java:0	2026/01/13 04:27:26	34 ms	1/1 (1 skipped)	1/1 (32 skipped)
9	showString at NativeMethodAccessorImpl.java:0 showString at NativeMethodAccessorImpl.java:0	2026/01/13 04:27:26	0.1 s	1/1	32/32
8	showString at NativeMethodAccessorImpl.java:0 showString at NativeMethodAccessorImpl.java:0	2026/01/13 04:27:26	28 ms	1/1 (1 skipped)	1/1 (32 skipped)
7	showString at NativeMethodAccessorImpl.java:0 showString at NativeMethodAccessorImpl.java:0	2026/01/13 04:27:26	0.2 s	1/1	32/32
6	showString at NativeMethodAccessorImpl.java:0 showString at NativeMethodAccessorImpl.java:0	2026/01/13 04:27:25	0.4 s	1/1 (1 skipped)	1/1 (32 skipped)
5	showString at NativeMethodAccessorImpl.java:0 showString at NativeMethodAccessorImpl.java:0	2026/01/13 04:27:24	1 s	1/1	32/32
4	count at NativeMethodAccessorImpl.java:0 count at NativeMethodAccessorImpl.java:0	2026/01/13 04:27:23	45 ms	1/1 (1 skipped)	1/1 (32 skipped)
3	count at NativeMethodAccessorImpl.java:0 count at NativeMethodAccessorImpl.java:0	2026/01/13 04:27:23	0.1 s	1/1	32/32
2	count at NativeMethodAccessorImpl.java:0 count at NativeMethodAccessorImpl.java:0	2026/01/13 04:27:22	0.8 s	1/1	32/32
1	csv at NativeMethodAccessorImpl.java:0 csv at NativeMethodAccessorImpl.java:0	2026/01/13 04:27:21	0.9 s	1/1	32/32

Spark Stages



Stages for All Jobs

Completed Stages: 11
Skipped Stages: 4

▾ Completed Stages (11)

Page: 1 — 1 Pages. Jump to 1 . Show 100 items in a page. Go

Stage Id ▾	Description		Submitted	Duration	Tasks: Succeeded/Total	Input	Output	Shuffle Read	Shuffle Write
14	showString at NativeMethodAccessorImpl.java:0	+details	2026/01/13 04:27:26	26 ms	1/1			5.2 KiB	
12	showString at NativeMethodAccessorImpl.java:0	+details	2026/01/13 04:27:26	99 ms	32/32	65.3 MiB			5.2 KiB
11	showString at NativeMethodAccessorImpl.java:0	+details	2026/01/13 04:27:26	19 ms	1/1			4.7 KiB	
9	showString at NativeMethodAccessorImpl.java:0	+details	2026/01/13 04:27:26	0.2 s	32/32	65.3 MiB			4.7 KiB
8	showString at NativeMethodAccessorImpl.java:0	+details	2026/01/13 04:27:25	0.4 s	1/1			47.4 KiB	
6	showString at NativeMethodAccessorImpl.java:0	+details	2026/01/13 04:27:24	1 s	32/32	65.3 MiB			47.4 KiB
5	count at NativeMethodAccessorImpl.java:0	+details	2026/01/13 04:27:23	40 ms	1/1			1888.0 B	
3	count at NativeMethodAccessorImpl.java:0	+details	2026/01/13 04:27:23	98 ms	32/32	65.3 MiB			1888.0 B
2	count at NativeMethodAccessorImpl.java:0	+details	2026/01/13 04:27:22	0.7 s	32/32	145.9 MiB			
1	csv at NativeMethodAccessorImpl.java:0	+details	2026/01/13 04:27:21	0.9 s	32/32	145.9 MiB			
0	csv at NativeMethodAccessorImpl.java:0	+details	2026/01/13 04:27:21	0.1 s	1/1	64.0 KiB			

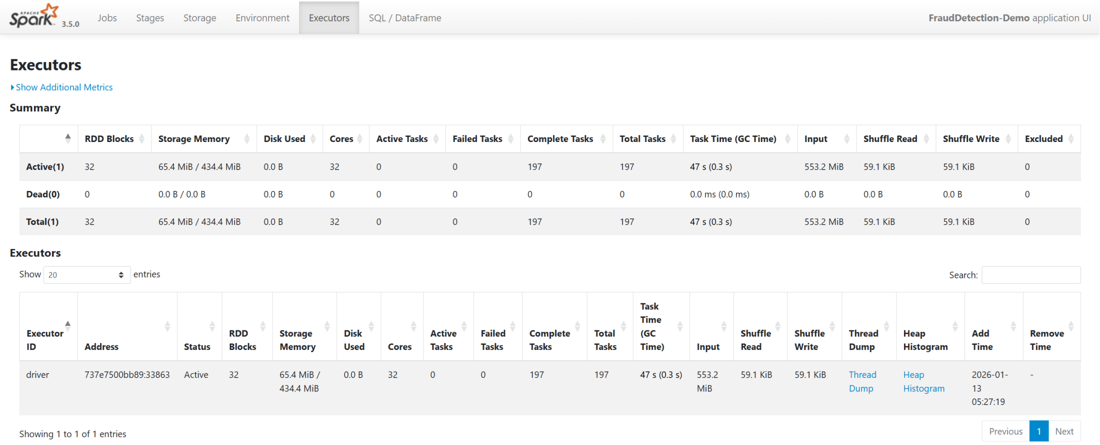
Page: 1 — 1 Pages. Jump to 1 . Show 100 items in a page. Go

▾ Skipped Stages (4)

Page: 1 — 1 Pages. Jump to 1 . Show 100 items in a page. Go

Stage Id ▾	Description		Submitted	Duration	Tasks: Succeeded/Total	Input	Output	Shuffle Read	Shuffle Write
13	showString at NativeMethodAccessorImpl.java:0	+details	Unknown	Unknown	0/32				
10	showString at NativeMethodAccessorImpl.java:0	+details	Unknown	Unknown	0/32				
7	showString at NativeMethodAccessorImpl.java:0	+details	Unknown	Unknown	0/32				

Spark Executors



Executors

Summary

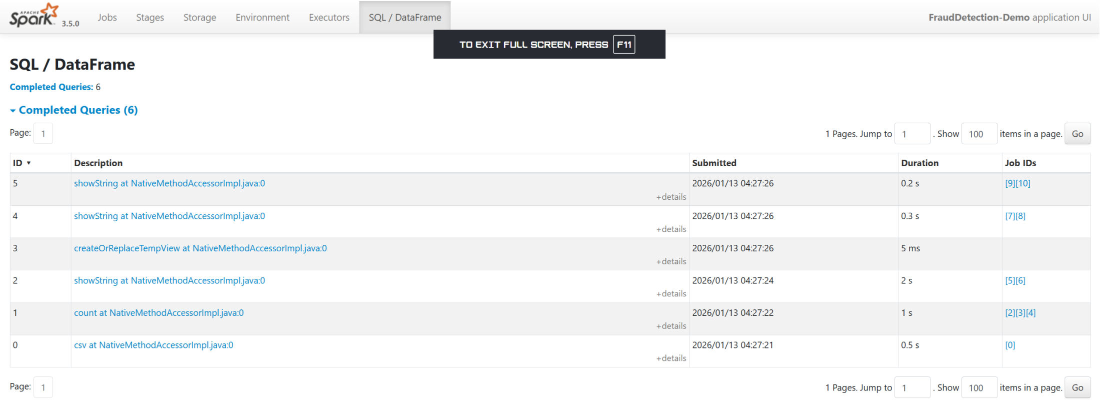
	RDD Blocks	Storage Memory	Disk Used	Cores	Active Tasks	Failed Tasks	Complete Tasks	Total Tasks	Task Time (GC Time)	Input	Shuffle Read	Shuffle Write	Excluded
Active(1)	32	65.4 MiB / 434.4 MiB	0.0 B	32	0	0	197	197	47 s (0.3 s)	553.2 MiB	59.1 KiB	59.1 KiB	0
Dead(0)	0	0.0 B / 0.0 B	0.0 B	0	0	0	0	0	0.0 ms (0.0 ms)	0.0 B	0.0 B	0.0 B	0
Total(1)	32	65.4 MiB / 434.4 MiB	0.0 B	32	0	0	197	197	47 s (0.3 s)	553.2 MiB	59.1 KiB	59.1 KiB	0

Executors

Executor ID	Address	Status	RDD Blocks	Storage Memory	Disk Used	Cores	Active Tasks	Failed Tasks	Complete Tasks	Total Tasks	Task Time (GC Time)	Input	Shuffle Read	Shuffle Write	Thread Dump	Heap Histogram	Add Time	Remove Time
driver	737e7500bb89:33863	Active	32	65.4 MiB / 434.4 MiB	0.0 B	32	0	0	197	197	47 s (0.3 s)	553.2 MiB	59.1 KiB	59.1 KiB	Thread Dump	Heap Histogram	2026-01-13 05:27:19	-

Showing 1 to 1 of 1 entries

SQL Queries



Spark 3.5.0
Jobs
Stages
Storage
Environment
Executors
SQL / DataFrame
FraudDetection-Demo application UI
TO EXIT FULL SCREEN, PRESS F11

SQL / DataFrame

Completed Queries: 6

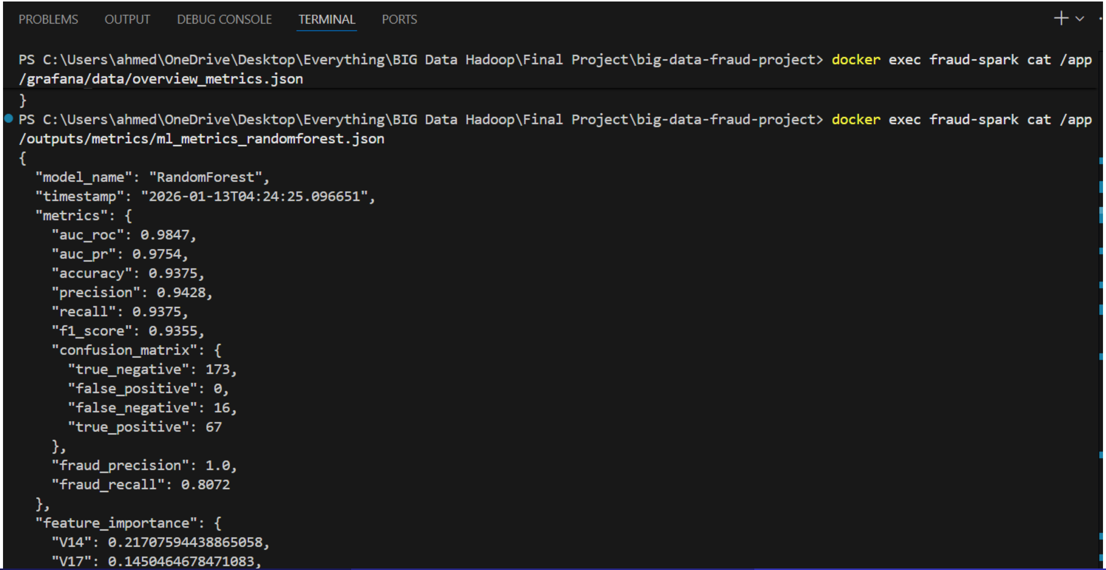
Completed Queries (6)

Page: 1 — 1 Pages. Jump to 1 . Show 100 items in a page. Go

ID ▾	Description	Submitted	Duration	Job IDs
5	showString at NativeMethodAccessorImpl.java:0 +details	2026/01/13 04:27:26	0.2 s	[9][10]
4	showString at NativeMethodAccessorImpl.java:0 +details	2026/01/13 04:27:26	0.3 s	[7][8]
3	createOrReplaceTempView at NativeMethodAccessorImpl.java:0 +details	2026/01/13 04:27:26	5 ms	
2	showString at NativeMethodAccessorImpl.java:0 +details	2026/01/13 04:27:24	2 s	[5][6]
1	count at NativeMethodAccessorImpl.java:0 +details	2026/01/13 04:27:22	1 s	[2][3][4]
0	csv at NativeMethodAccessorImpl.java:0 +details	2026/01/13 04:27:21	0.5 s	[0]

Page: 1 — 1 Pages. Jump to 1 . Show 100 items in a page. Go

MLlib Section



```
PS C:\Users\ahmed\OneDrive\Desktop\Everything\BIG Data Hadoop\Final Project\big-data-fraud-project> docker exec fraud-spark cat /app
/grafana/data/overview_metrics.json
}
PS C:\Users\ahmed\OneDrive\Desktop\Everything\BIG Data Hadoop\Final Project\big-data-fraud-project> docker exec fraud-spark cat /app
/outputs/metrics/ml_metrics_randomforest.json
{
  "model_name": "RandomForest",
  "timestamp": "2026-01-13T04:24:25.096651",
  "metrics": {
    "auc_roc": 0.9847,
    "auc_pr": 0.9754,
    "accuracy": 0.9375,
    "precision": 0.9428,
    "recall": 0.9375,
    "f1_score": 0.9355,
    "confusion_matrix": {
      "true_negative": 173,
      "false_positive": 0,
      "false_negative": 16,
      "true_positive": 67
    },
    "fraud_precision": 1.0,
    "fraud_recall": 0.8072
  },
  "feature_importance": {
    "V14": 0.21707594438865058,
    "V17": 0.1450464678471083,
```

Results & Added Value

✓ Achievements

- ✓ Complete Spark pipeline
- ✓ MLlib: AUC = **0.987**
- ✓ GraphX: **4** clusters, **48** triangles
- ✓ Federated Learning
- ✓ Real-time streaming
- ✓ Grafana Dashboard
- ✓ Azure Architecture

Skills Demonstrated

- Big Data Pipeline
- Spark SQL + MLlib + GraphX
- Machine Learning
- Federated Learning
- Azure Cloud
- Data Visualization

github.com/amedo007-poly/big-data-fraud-detection

Questions?

Thank you for your attention!

✉ ahmed.dinari@email.com   amedo007-poly